



(43) International Publication Date
17 March 2016 (17.03.2016)

- (51) International Patent Classification:
E21B 44/00 (2006.01) *E21B 41/00* (2006.01)
- (21) International Application Number:
PCT/US2015/048490
- (22) International Filing Date:
4 September 2015 (04.09.2015)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
14/483,463 11 September 2014 (11.09.2014) US
- (71) Applicant: **BAKER HUGHES INCORPORATED**
[US/US]; P.O. Box 4740, Houston, Texas 77210-4740 (US).
- (72) Inventors: **FORSTNER, Ingo**; 2929 Allen Parkway, Suite 2100, Houston, TX 77019-2118 (US). **LINKE, Christian**; 2929 Allen Parkway, Suite 2100, Houston, TX 77019-2118 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: METHOD OF DETERMINING WHEN TOOL STRING PARAMETERS SHOULD BE ALTERED TO AVOID UNDESIRABLE EFFECTS THAT WOULD LIKELY OCCUR IF THE TOOL STRING WERE EMPLOYED TO DRILL A BOREHOLE AND METHOD OF DESIGNING A TOOL STRING

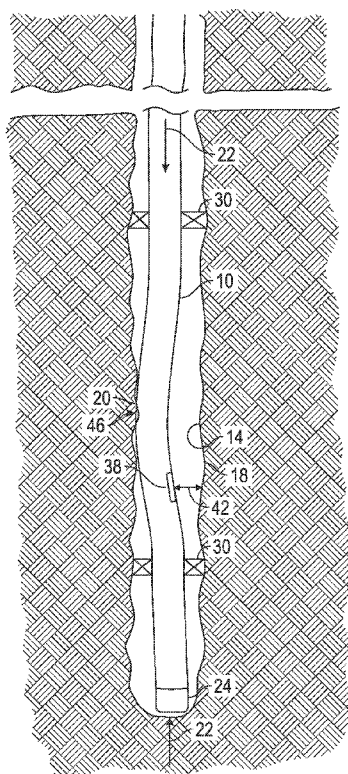


FIG. 2

(57) Abstract: A method of determining when tool string parameters should be altered to avoid undesirable effects that would likely occur if the tool string were employed to drill a borehole includes, modeling portions or an entirety of the tool string in the borehole under steady state loading conditions, identifying deflections of the tool string with the modeling when buckling would occur for specific tool string parameters, and calculating whether whirl exhibiting similar deflections of the tool string to those identified during buckling would be undesirable.

**Declarations under Rule 4.17:**

- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

- *with international search report (Art. 21(3))*

METHOD OF DETERMINING WHEN TOOL STRING PARAMETERS SHOULD BE
ALTERED TO AVOID UNDESIRABLE EFFECTS THAT WOULD LIKELY OCCUR IF
THE TOOL STRING WERE EMPLOYED TO DRILL A BOREHOLE AND METHOD OF
DESIGNING A TOOL STRING

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Application No. 14/483463, filed on September 11, 2014, which is incorporated herein by reference in its entirety.

BACKGROUND

[0002] Whirl is a dynamic condition that can be experienced during rotational operation of a tool string in a borehole, such as while drilling a borehole into an earth formation, for example. Depending upon operational parameters the whirl can be damaging to the tool string and as such operators frequently try to avoid whirl completely. This approach, if successful at avoiding whirl, achieves its desired objective. However, new methods and systems that deal with avoiding undesirable effects associated with whirl are of interest to those who practice in the art.

BRIEF DESCRIPTION

[0003] Disclosed herein is a method of determining when tool string parameters should be altered to avoid undesirable effects that would likely occur if the tool string were employed to drill a borehole. The method includes, modeling portions or an entirety of the tool string in the borehole under steady state loading conditions, identifying deflections of the tool string with the modeling when buckling would occur for specific tool string parameters, and calculating whether whirl exhibiting similar deflections of the tool string to those identified during buckling would be undesirable.

[0004] Further disclosed herein is a method of designing a tool string. The method includes, modeling the tool string, applying simulated loads at steady state on the tool string as modeled that create buckling, determining whether whirl of the tool string with a similar deflection and contact force distribution as simulated buckling will be undesirable, and setting design parameters that allow buckling of the modeled tool string as long as whirling at similar deflection and contact force distribution as simulated buckling is not undesirable.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] The following descriptions should not be considered limiting in any way. With reference to the accompanying drawings, like elements are numbered alike:

[0006] FIG. 1 depicts a schematical cross sectional view of a tool string within a borehole; and

[0007] FIG. 2 depicts a similar schematical cross sectional view of the tool string within the borehole with the tool string being shown in a deformed condition.

DETAILED DESCRIPTION

[0008] A detailed description of one or more embodiments of the disclosed apparatus and method are presented herein by way of exemplification and not limitation with reference to the Figures.

[0009] Referring to Figures 1 and 2, buckling of a tool string 10, such as a drill string or drill pipe, occurs when the tool string 10 has deformed in bending to a point where the tool string 10 makes contact with walls 14 of a borehole 18, for example. This can occur under static or steady state conditions, such as when the tool string 10 is not rotating, for example. If the tool string 10 is rotating relative to the borehole 18 and contact is made between the tool string 10 and the walls 14 a dynamic condition known as whirl can occur. Whirl is when the tool string 10 continues to make contact with the walls 14 while it is rotating and the contact point 20 between the tool string 10 and the walls 14 also rotates. The whirl can be in a forward or a backward direction depending upon the direction of rotation of the contact point 20 relative to the direction of rotational of the tool string 10 itself. Whirling can have detrimental effects on operations and in such cases may be undesirable. Undesirable conditions include excess bending fatigue, excess dynamic wall contact forces (these can create frictional wear and impact loading on the string and damage to the borehole wall), and sensor measurement accuracy degradation and sensor damage, for example. The impact forces can be based on assumptions, estimates, measurements, or analytically derived values of lateral acceleration inside the borehole 18 and at surfaces of the walls 14. However, not all whirl necessarily causes all or even any of these undesirable conditions. Determining when whirl is likely to cause these undesirable conditions can be helpful in deciding whether to allow operations to continue even while whirl continues or to alter operating parameters to lessen the undesirable conditions. It can also be helpful in planning the design of a tool string by choosing a design that exhibits no or limited undesirable effects in cases where whirl may develop.

[0010] Embodiments disclosed herein include a method of determining when parameters of the tool string 10 should be altered to avoid undesirable effects and providing guidance on altering parameters of the tool string 10 to avoid undesirable conditions. One embodiment includes modeling portions or the entirety of the tool string 10 relative to the borehole 18 in steady state loading conditions, identifying from the modeling if buckling would occur under the steady state loading conditions and how the resulting deflections would look, calculating whether whirl with similar deflections and load conditions as the steady state loading conditions defined by the modeled buckling shape would be undesirable.

[0011] Several factors contribute to whether buckling will occur and contributions of such factors can be calculated. For example, axial compression of the tool string 10, expressed by arrows 22 in the Figures, adds to weight of the tool string 10 in determining a weight applied to a drill bit 24 when the tool string 10 is a drill string used for drilling, for example. This weight on bit or WOB can be a major contributor to buckling in applications where the tool string 10 includes a bottom hole assembly, for example. Another factor is a longitudinal dimension 26 between adjacent stabilizers 30 or centralizers. Typically the greater the dimension 26 the greater the likelihood that buckling will occur. Having a tool string 10 with a large dimension 26, however, can result in less stress in the tool string 10 if only a single one of the contact points 20 exists during whirl since the greater dimension 26 means a larger radius of curvature in the tool string 10. A further factor is diametrical dimensions of the stabilizers 30 and portions of the tool string 10 in between the stabilizers 30. Typically the smaller the outer diameter and the greater the inner diameter of the portions, the greater the likelihood that buckling will occur. Stated another way, a decrease in stiffness of a portion of the tool string 10 between stabilizers 30 the greater the likelihood that buckling will occur. Assumptions can be made regarding curvature of the tool string 10 relative to the dimension 26 with one assumption being that just the single contact point 20 occurs at approximately midway between adjacent stabilizers 30 that define the dimension 26. Radial clearance 34 between the tool string 10 and the borehole walls 18 can also be a factor. The smaller the radial clearance 34 is the more likely buckling is to occur since less radial deformation of the tool string 10 is required before it contacts the walls 14. However, undesirable conditions may also be lessened in systems wherein the radial clearance 34 is small since loads associated with contact between the tool string 10 and the walls 14 may also be less. Sagging of the tool string 10 due to weight of the tool string 10 in deviated and horizontal portions of the borehole 18 (such as when the borehole 18 is a wellbore in an earth formation, for example), also contributes to buckling. All other things being equal, the

greater the sagging the more likely buckling will occur. By modeling these and other parameters with finite element modeling software, for example, calculations can be made to determine at what point buckling will occur and what deflection shapes are likely. Additionally, the accuracy of the modeling and calculations can be improved by analyzing and incorporating results taken empirically. Additionally, variations in the foregoing parameters can be modeled to determine their individual contributions to the deflection shapes.

[0012] The foregoing modeling allows an operator to determine load conditions experienced by the tool string 10. These include such parameters as the stress in the tool string 10 due to bending that results in the buckling and force applied between the tool string 10 and the walls 14 at the contact point 20 therebetween, for example. Calculations can be made employing these parameters to determine whether whirl of a similar deflection geometry as those that create buckling will be undesirable and thus be allowed or not. A curvature of the borehole 14 can also be factored into the calculations since such curvature will contribute to the bending loads in the tool string 10.

[0013] For example, whirl creates cyclic bending of the tool string 10. In fact, backwards whirl can cause ten or more whirl rotations for each rotation of the tool string 10. This directly correlates to 10 or more bending cycles of the tool string 10 for each rotation of the tool string 10. By knowing the amount of bending stress that the whirl would cause in the tool string it can be calculated whether fatigue failure of the tool string 10 will likely occur over a specific period of operation. Whirl deflections can be similar to buckling deflections for the same tool string 10. Therefore bending loads, contact forces, deflections, and lateral misalignment can be estimated for whirl events by reviewing one or more buckling shapes of the tool string 10. If these calculations predict that undesirable fatigue conditions would likely occur then directions can be provided as to the steady state loading parameters that can be altered to a level wherein the calculation predicts acceptable fatigue conditions of the tool string 10. Altering the radial clearance 34 to a smaller value to decrease stress generated in the tool string 10 during each bending cycle is one such alterable parameter that guidance can be provided for. This reduction in bending stress can be to a level that the tool string 10 may undergo essentially an infinite number of bending cycles without causing significant fatigue concerns.

[0014] Another alterable parameter that can decrease loads in the tool string 10 due to bending is changing the dimension 26 between adjacent stabilizers 30. All other things being

equal, including stiffness of the tool string 10, for example, may allow an increase in the dimension 26 to decrease bending stress in the tool string 10.

[0015] A different alteration could be employed in instances where accuracy of one or more sensors 38 disposed at the tool string 10 is negatively affected by whirl. These inaccuracies can be calculated and may be due to changes in a dimension 42 between the sensor 38 and the walls 14 as well as other relationships between the sensor 38 and the walls 14, such as, curvature, speed and angle, for example. Such changes in the dimension 42 may be due to the displacement of a portion of the tool string 10 where the sensor 38 is located moving an axis of the tool string 10 off center of the borehole 18. For example, in embodiments wherein the sensor 38 is located near a surface of the tool string 10 whirl can cause the dimension 42 to change with every whirl rotation. An alteration that decreases the radial clearance 34 therefore can lessen the variations to the dimension 42 caused by whirl. Another alteration that can decrease variability in a value of the dimension 42 includes relocating the sensor 38 nearer to one of the stabilizers 30. In so doing the amount an axis of the tool string 10 deviates from a center of the borehole 18 decreases for a given bend radius of the tool string 10.

[0016] Another example of an undesirable condition relates to friction between the tool string 10 and the walls 14. Frictional wear of the tool string 10 can be proportional to, among other things, the normal force between the tool string 10 and the walls 14 at the contact point 20. These normal forces at a plurality of the contact points 20 can be calculated individually or cumulatively. The normal forces can be calculated quite accurately under steady state loading conditions that cause buckling. By assuming these normal forces are similar during whirl as they are during buckling frictional wear of the tool string 10 can be calculated. These calculations include extrapolating a relative distance traveled between a surface 46 of the tool string 10 and the walls 14 at the contact point 20 that will occur due to whirl.

[0017] Friction between the tool string 10 and the walls 14 can also cause issues with integrity of the wellbore 18 as well as causing problems with torque or drag.

[0018] Frictional engagement between the tool string 10 and the walls 14 can also cause excess vibration in the tool string 10 that can negatively affect accuracy of the sensor 38 or can damage the sensor 38. The likelihood and severity of such damage in case of whirl can be estimated from buckling simulation.

[0019] Alternately, instead of using a steady-state worst case bending scenario derived from modeling in the planning phase or in realtime, the whirl and bending load

measurements at one position in the tool string 10 are extrapolated to the entire tool string 10. This can include scaling the worst case bending load distribution to one that matches the measured bending load at the one position. Or optionally considering whirl frequency or bending load frequency as a multiplier of the severity. As such, instead of just stating that whirl is acceptable or undesirable, bending load and contact force distribution values (along with the whirl frequency) could be quantified to generate a whirl severity index. With statistical offset data, statements like “expect twist-off in about 30 minutes at these parameters” could be made. Although this has been described in relation to the tool string 10 used for drilling, it can relate to any string inside a long hole that is rotating, such as, a casing or liner, a drillpipe higher above in the string, a milling BHA, a workover BHA, and a long bore drilling in the workshop, for example.

[0020] While the invention has been described with reference to an exemplary embodiment or embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the claims. Also, in the drawings and the description, there have been disclosed exemplary embodiments of the invention and, although specific terms may have been employed, they are unless otherwise stated used in a generic and descriptive sense only and not for purposes of limitation, the scope of the invention therefore not being so limited. Moreover, the use of the terms first, second, etc. do not denote any order or importance, but rather the terms first, second, etc. are used to distinguish one element from another. Furthermore, the use of the terms a, an, etc. do not denote a limitation of quantity, but rather denote the presence of at least one of the referenced item.

CLAIMS

What is claimed is:

1. A method of determining when tool string (10) parameters should be altered to avoid undesirable effects that would likely occur if the tool string (10) were employed to drill a borehole (18), comprising:

modeling portions or an entirety of the tool string (10) in the borehole (18) under steady state loading conditions;

identifying deflections of the tool string (10) with the modeling when buckling would occur for specific tool string (10) parameters; and

calculating whether whirl exhibiting similar deflections of the tool string (10) to those identified during buckling would be undesirable.

2. The method of claim 1, further comprising varying the specific tool string (10) parameters during the modeling.

3. The method of claim 1, further comprising determining a contribution that a dimension (26) between adjacent stabilizers (30) has to buckling of the tool string (10).

4. The method of claim 1, further comprising determining a contribution that radial clearance (34) between the tool string (10) and walls (14) of the borehole (18) has to buckling of the tool string (10).

5. The method of claim 1, further comprising calculating where the tool string (10) will make contact with walls (14) of the borehole (18).

6. The method of claim 1, further comprising calculating individual and/or cumulative normal forces between the tool string (10) and walls (14) of the borehole. (18)

7. The method of claim 1, further comprising calculating fatigue of the tool string (10).

8. The method of claim 1, further comprising calculating frictional wear of the tool string (10) against walls (14) of the borehole (18).

9. The method of claim 1, further comprising calculating impact forces between the tool string (10) and walls (14) of the borehole (18) using assumptions, estimates, measurements, and analytically derived values of lateral acceleration.

10. The method of claim 1, further comprising calculating inaccuracies of at least one sensor (38) disposed in the tool string (10) due to variations in a relationship between the at least one sensor (38) and walls (14) of the borehole (18).

11. The method of claim 1, further comprising calculating damage to at least one sensor (38) disposed in the tool string (10).

12. The method of claim 1, further comprising assuming the whirl is backwards whirl.

13. The method of claim 1, wherein portions of the tool string (10) modeled include a bottom hole assembly positioned within a borehole (18) in an earth formation.

14. A method of designing a tool string (10) comprising:
modeling the tool string (10);
applying simulated loads at steady state on the tool string (10) as modeled that create buckling;

determining whether whirl of the tool string (10) with a similar deflection and contact force distribution as simulated buckling will be undesirable; and

setting design parameters that allow buckling of the modeled tool string (10) as long as whirling at similar deflection and contact force distribution as simulated buckling is not undesirable.

15. The method of claim 13, wherein the setting design parameters includes setting dimensions of stabilizers on the tool string (10).

1/2

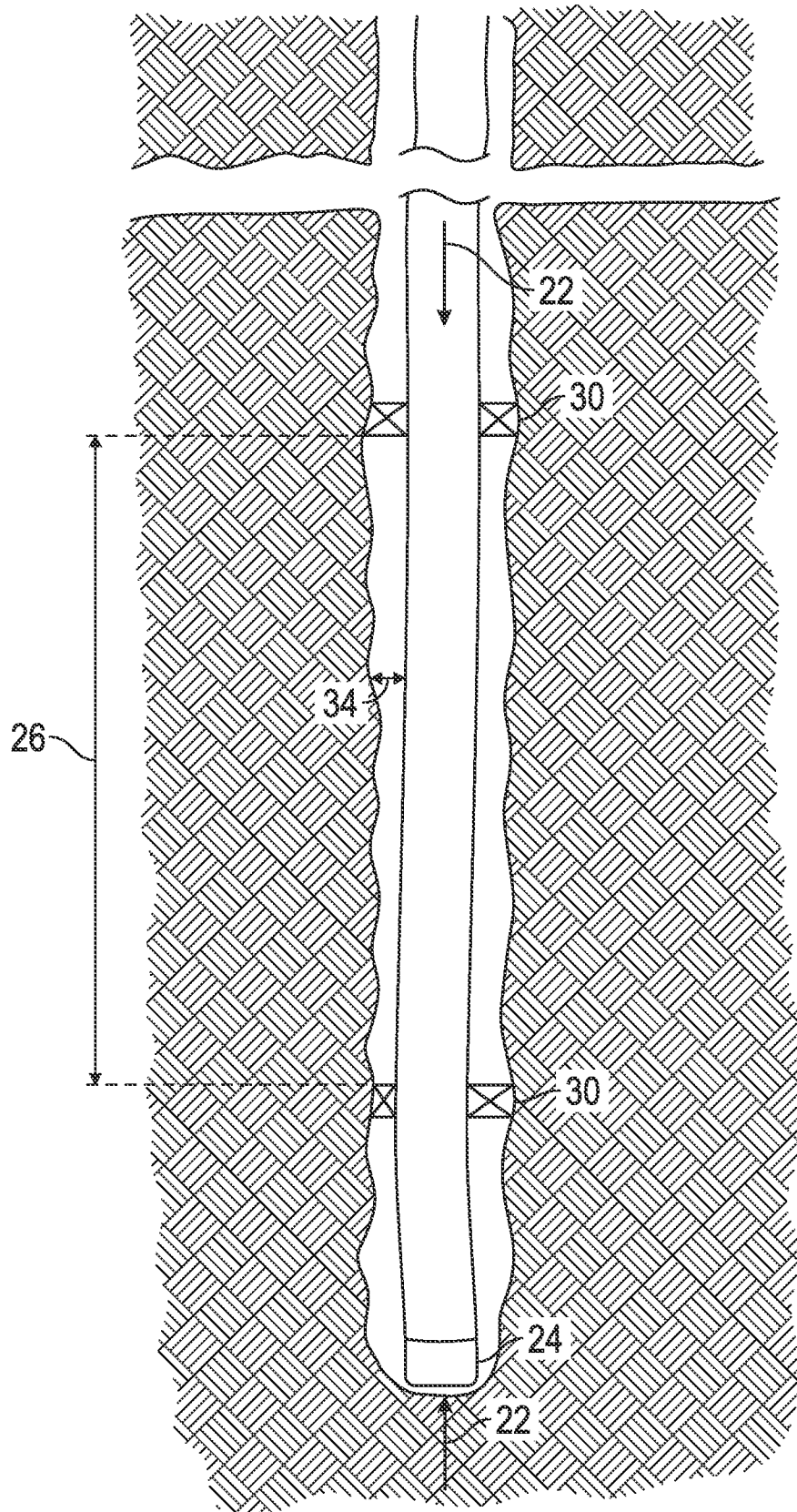


FIG. 1

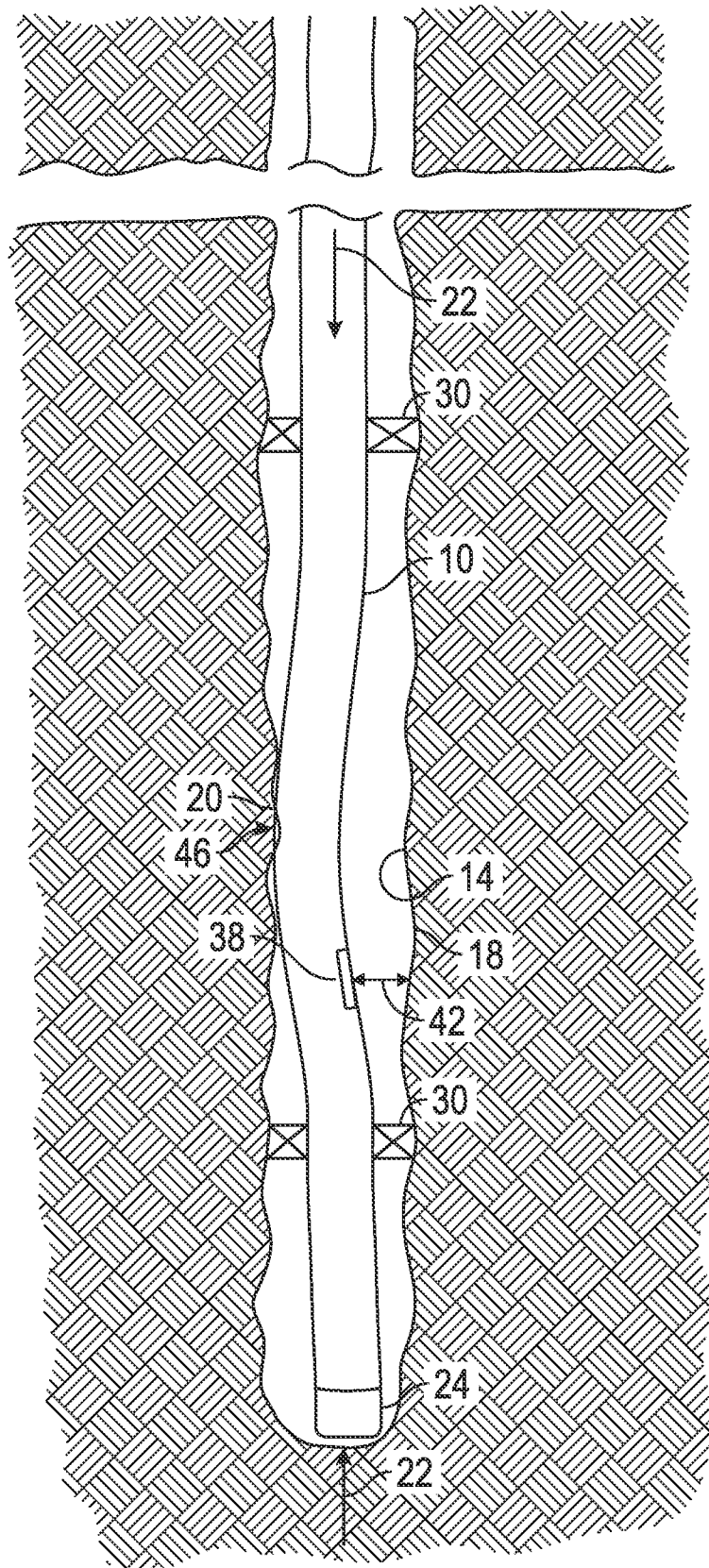


FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/048490**A. CLASSIFICATION OF SUBJECT MATTER****E21B 44/00(2006.01)i, E21B 41/00(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E21B 44/00; E21B 47/024; G06G 7/48; G01V 9/00; E21B 47/18; E21B 7/04; E21B 41/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: tool string, parameter, modeling, deflection, stabilizer, wall, dimension, buckling, whirl

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2013-0098683 A1 (TURNER et al.) 25 April 2013 See paragraphs [0014]-[0063], [0114]-[0123], [0162]-[0214].	1-15
A	US 2006-0065440 A1 (HUTCHINSON, MARK W.) 30 March 2006 See paragraphs [0059]-[0079] and figures 1, 15-16.	1-15
A	US 2006-0260843 A1 (COBERN, MARTIN E.) 23 November 2006 See paragraphs [0033]-[0047], [0057]-[0061] and figures 1, 6.	1-15
A	US 2006-0195307 A1 (HUANG et al.) 31 August 2006 See paragraphs [0134]-[0156] and figures 13-14.	1-15
A	US 4384483 A (DELLINGER et al.) 24 May 1983 See column 2, line 46 - column 3, line 31 and figure 1.	1-15



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

18 November 2015 (18.11.2015)

Date of mailing of the international search report

23 November 2015 (23.11.2015)

Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea

Facsimile No. +82-42-472-7140

Authorized officer

RHEE, Jun Ho

Telephone No. +82-42-481-8288



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2015/048490

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2013-0098683 A1	25/04/2013	CA 2788116 A1	04/08/2011
		CN 102822752 A	12/12/2012
		CN 102822752 B	22/07/2015
		GB 2492906 A	16/01/2013
		US 2011-0186353 A1	04/08/2011
		US 2013-0092438 A1	18/04/2013
		US 2014-0251688 A1	11/09/2014
		US 8453764 B2	04/06/2013
		US 8640791 B2	04/02/2014
		US 8684108 B2	01/04/2014
		WO 2011-094689 A1	04/08/2011
US 2006-0065440 A1	30/03/2006	AU 2003-223424 A1	03/11/2003
		AU 2003-224831 A1	03/11/2003
		AU 2003-230798 A1	03/11/2003
		CA 2482912 A1	30/10/2003
		CA 2482912 C	12/05/2009
		CA 2482922 A1	30/10/2003
		CA 2482922 C	17/06/2008
		CA 2482931 A1	30/10/2003
		CA 2482931 C	17/06/2008
		CA 2603653 A1	30/10/2003
		CA 2603653 C	19/10/2010
		CA 2604810 A1	30/10/2003
		CA 2604810 C	06/07/2010
		CA 2615481 A1	30/10/2003
		CA 2615481 C	31/08/2010
		CA 2620905 A1	30/10/2003
		CA 2620905 C	12/07/2011
		EP 1502003 A2	02/02/2005
		EP 1502004 A1	02/02/2005
		EP 1502005 A1	02/02/2005
		US 2005-0060096 A1	17/03/2005
		US 2005-0071120 A1	31/03/2005
		US 2005-0087367 A1	28/04/2005
		US 2006-0266552 A1	30/11/2006
		US 2006-0266553 A1	30/11/2006
		US 2006-0272861 A1	07/12/2006
		US 7044238 B2	16/05/2006
		US 7114578 B2	03/10/2006
		US 7114579 B2	03/10/2006
		US 7140452 B2	28/11/2006
		US 7306054 B2	11/12/2007
		US 7316278 B2	08/01/2008
		US 7318488 B2	15/01/2008
		WO 03-089751 A2	30/10/2003
		WO 03-089758 A1	30/10/2003
		WO 03-089759 A1	30/10/2003
		WO 2003-089751 A3	08/01/2004

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2015/048490

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2006-0260843 A1	23/11/2006	US 7681663 B2 WO 2006-119294 A1	23/03/2010 09/11/2006
US 2006-0195307 A1	31/08/2006	AU 2001-26462 A1 CA 2340547 A1 CA 2340547 C CA 2358618 A1 CA 2358618 C CA 2522162 A1 CA 2522162 C CA 2531397 A1 CA 2531397 C CA 2531717 A1 CA 2536684 A1 CA 2536684 C CA 2536695 A1 CA 2536695 C CA 2541478 A1 CA 2541478 C CA 2567656 A1 CA 2582200 A1 CA 2582200 C CA 2598801 A1 CA 2598801 C CA 2734730 A1 CA 2748423 A1 CA 2748424 A1 CA 2748559 A1 CA 2748690 A1 GB 2360304 A GB 2367843 A GB 2370059 A GB 2370060 A GB 2414315 A GB 2419014 A GB 2419015 A GB 2420203 A GB 2420862 A GB 2424975 A GB 2435706 A GB 2436451 A GB 2436451 B US 2003-0195733 A1 US 2004-0143427 A1 US 2004-0211596 A1 US 2005-0010382 A1 US 2005-0015229 A1 US 2005-0080595 A1 US 2005-0096847 A1 US 2005-0133272 A1	27/09/2001 13/09/2001 13/12/2005 11/04/2002 06/12/2005 13/09/2001 22/05/2007 27/01/2005 13/04/2010 27/01/2005 27/01/2005 11/10/2011 27/01/2005 10/05/2011 06/10/2006 23/06/2009 01/12/2005 21/09/2007 26/01/2010 01/03/2008 20/09/2011 27/01/2005 27/01/2005 27/01/2005 27/01/2005 27/01/2005 19/09/2001 17/04/2002 19/06/2002 19/06/2002 23/11/2005 12/04/2006 12/04/2006 17/05/2006 07/06/2006 11/10/2006 05/09/2007 26/09/2007 14/01/2009 16/10/2003 22/07/2004 28/10/2004 13/01/2005 20/01/2005 14/04/2005 05/05/2005 23/06/2005

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2015/048490

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		US 2005-0154568 A1	14/07/2005
		US 2005-0159937 A1	21/07/2005
		US 2005-0165589 A1	28/07/2005
		US 2005-0165592 A1	28/07/2005
		US 2005-0273301 A1	08/12/2005
		US 2005-0273302 A1	08/12/2005
		US 2005-0273304 A1	08/12/2005
		US 2006-0149518 A1	06/07/2006
		US 2007-0005316 A1	04/01/2007
		US 2007-0021857 A1	25/01/2007
		US 2007-0067147 A1	22/03/2007
		US 2007-0192071 A1	16/08/2007
		US 2010-0211362 A1	19/08/2010
		US 2011-0035200 A1	10/02/2011
		US 6516293 B1	04/02/2003
		US 6785641 B1	31/08/2004
		US 6873947 B1	29/03/2005
		US 7020597 B2	28/03/2006
		US 7139689 B2	21/11/2006
		US 7251590 B2	31/07/2007
		US 7260514 B2	21/08/2007
		US 7356450 B2	08/04/2008
		US 7426459 B2	16/09/2008
		US 7464013 B2	09/12/2008
		US 7693695 B2	06/04/2010
		US 7844426 B2	30/11/2010
		US 7899658 B2	01/03/2011
		US 7954559 B2	07/06/2011
		US 8082134 B2	20/12/2011
		US 8185366 B2	22/05/2012
		US 8589124 B2	19/11/2013
		WO 2005-008019 A1	27/01/2005
		WO 2005-008020 A1	27/01/2005
		WO 2005-008021 A1	27/01/2005
		WO 2005-008022 A1	27/01/2005
		WO 2005-114542 A2	01/12/2005
		WO 2005-114542 A3	06/04/2006
US 4384483 A	24/05/1983	None	